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§5. Improvement of Compact Torus Injector for Fuelling LHD

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The SPICA (SPeromak Injector using Conical Accelerator) has been developed for an advanced fueler into LHD by the method of Compact Toroid (CT) injection. The SPICA injector has achieved CT parameters to penetrate into LHD plasmas at a magnetic field of B = 0.8 T. However, when a CT plasma is practically injected into a LHD plasma, the CT transport in long distance from the injector to the plasma core and the injection at a higher B can cause problems for central fueling. The injector is required to enhance the performance much more than previously obtained. We have thus investigated issues on the structure and properties of the SPICA (L-type) to enhance the performance.

In the previous experiments, although CT speed has successfully achieved about 200 km/s, CT magnetic field and density have decreased on the stages of CT acceleration and ejection. To prevent the deterioration in CT parameters, we have focused on investigation of the characteristics of CT plasmas being accelerated and ejected since the last fiscal year. The experiments have been conducted on the S-type SPICA injector with half the length of the accelerator of the L-type one. The injector is connected with a flux conserver (FC) to observe an ejected CT plasma. In this fiscal year, we have studied the property of the M-type SPICA with a half the length of the S-type accelerator. The experimental setup is shown in Fig. 1. PIN diodes are mounted at 4 P-ports for the observation of CT transit to calculate CT speed. In the FC, the He-Ne laser interferometer measures the line-averaged electron density of a CT plasma. The magnetic probe arrays also provide magnetic field profile measurements of the CT.

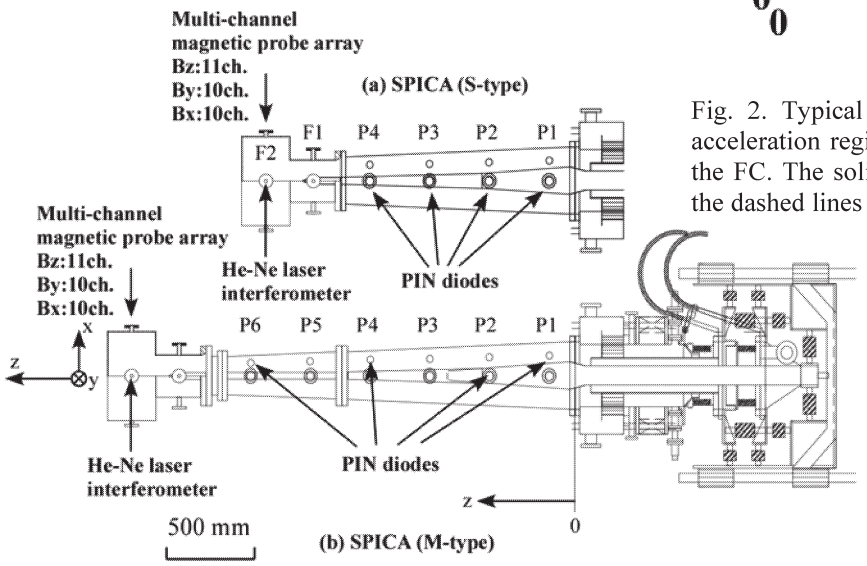

Fig. 1. Measurement system for the SPICA injectors of S and M-type.

Figure 2 shows the typical time evolution of PIN diode signals and the CT density on the S and M-type SPICA injector. These injectors were operated for the current fed through the bias poloidal coil, I_{bias} = 210 A, and the charging voltage on the formation bank, $V_{form.}$ = 8 kV for the both types, and the voltage on the acceleration bank, $V_{acc.}$ = 12 kV for the S-type and 15 kV for the M-type. Here, CT speeds between VL2 and VL4 (P2 and P4), $v_{CT,VL2\text{-}4}$ are estimated at 77 km/s on the S-type and 88 km/s on the M-type. That between VL4 and VL5 (P4 and P6) just before CT ejection on the M-type, $v_{CT,VL4\text{-}5}$ is at 206 km/s. Although CT speed depends on the accelerator voltage, the difference of $v_{CT,VL2\text{-}4}$ between the S and M-type is less than that predicted from the disparity in the accelerator voltage. In contrast, the difference between $v_{CT,VL2\text{-}4}$ and $v_{CT,VL4\text{-}5}$ exhibits obvious effect of the disparity in the accelerator length. In addition, the magnetic field profiles in the FC indicated a typical spheromak configuration on both the S and M-type injectors, and the peaked CT density is above 8 × 10^{20} m^{-3} in the FC. In these experiments, the noise in observed signals, which occur when a CT plasma is ejected from the injector, are extremely lower than those in previous experiments on the L-type SPICA. This indicates that a CT plasma is successfully released from the acceleration current and ejected form the injector, resulting in enhancement of CT parameters. Through the series of experiments, the CT accelerator can be optimized at the length between M and L-type and the SPICA injector will be effectively improved.

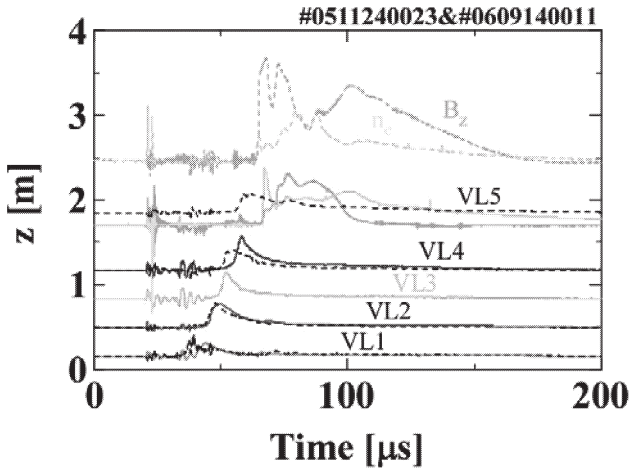

Fig. 2. Typical evolution of PIN diode signals in the acceleration region and line-averaged electron density in the FC. The solid lines represent the S-type injector and the dashed lines the M-type one.